

Living Vertebrate Sample Return Mission from Mars Orbit

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Introduction:

Understanding the impact of long duration exposure to the space environment on the human is vital to managing the health risks and physiological challenges to future manned missions. Specific interventions will need to be designed to mitigate this impact and help the crew transit and live safely in space. Our knowledge of the consequences of long duration space on human health is inferential. We have no biological sample return of any vertebrate species exposed to deep space upon which to analyze, evaluate, model and predict the outcome of the mission. This present proposal seeks to fill this critical gap using a proven vertebrate model that has provided inferential data from LEO. An automated, robotic system for life support during a lunar and Mars mission will be created. In-flight monitoring of the physiological state is proposed, and extensive post-flight biological experiments will be conducted to determine the long-term consequences on animal functionality. This proposal is unique in that it provides an ongoing living model of the viability and adaptation of biological systems to prolonged deep space flight. The specimen itself is the primary instrument with which the cumulative effects of the environment, such as chronic exposure to a zero-gravity and low dose radiation penetration, will be measured. The project will also drive technology advances in life support and specific medical tools necessary to help monitor and diagnose human health.

General Description:

To assure successful manned missions the effects on astronaut's health and functionality is required to manage the risks involved in habitation of the lunar surface and to travel safely beyond the confines of the Earth-Moon orbit. A critical aspect is to understand the long-term effects and challenges of deep space flight on the physiology of living organisms, in particular a vertebrate species, and the subsequent countermeasures that must be taken to assure physical health. How prolonged exposure to zero gravity and chronic radiation penetration influence the organism is unknown. This proposal is unique in that it provides an ongoing, living model of the viability and adaptation of biological systems to prolonged deep space flight. The specimen itself is the primary instrument will measure the cumulative effects of the environment, and the project will drive technology advances in life support and specific medical tools necessary to help monitor and diagnose human health.

This is a direct precursor for the goal of Transit/Return to Mars with Vertebrate Biological Sample return. This payload does not have to land on the surface of Mars. This proposal is unique in that it provides an ongoing model of the viability and adaptation of biological systems to prolonged deep space flight. The specimen is the instrument that will measure the individual and synergistic effects of the deep space environment, and the project will drive technology advances in life support and specific medical tools necessary to help monitor and diagnose human health.

Selected vertebrate model is the toadfish, *Opsanus tau*, because: 1) cellular mechanisms for sensory transduction of gravito-inertial forces are remarkably similar between fish and higher vertebrates, and its response to μG is directly correlated with re-adaptation to gravity experienced by astronauts. 2) a life cycle >40 years, and thus aging and natural death are not issues as in rodents and non-vertebrate species. Its development is a progressive enlargement, without radical events, and juveniles weighing 20-40 gm are excellent subjects. 3) Its metabolism and habitat allow mission span to be extended without an exponential increase in resources (power, weight) and complexity (waste management) that would be seen with a rodent model. It enters into a low metabolic state when confronted with cold. Thus, it could be transitioned from an active to a state of stasis to conserve energy or to provide radioprotection. 4) It is capable of surviving long periods without food.

In-flight Monitoring. Lower power micro-scanners will be available to produce a significant understanding of biological changes while staying within the power consumption constraints. New functional reconstruction techniques, data fusion methods, and the use of reconfigurable computing hardware for low power, near real-time processing of imaging data are currently being developed for *in-situ* analysis. This species naturally seek enclosures for attack predation and nesting, and we will take advantage of this behavior in the design of imaging and bio-instrumentation telemetry components for short range induction charging of sensors and automated information transmission.

Post-flight Studies. Our ability to design specific countermeasures to help the crew transit and live safely in space is limited by our understanding biological response to this challenge. One such system is the equilibrium organ. The effect of long-term exposure on the vestibular structures is not known, but evidence from MIR and ISS suggest that individuals transition from an initial hypersensitivity to a hyposensitivity in later stages of the mission. This poses serious challenges to the explorers. We need to identify the cellular and molecular changes that occur in critical structures such as the inner ear, the retina, the central nervous system, the heart and lungs, the kidneys, GI tract, bone and muscle. The optimal scenario is a have the specimens returned to Earth for extensive battery of studies to completely evaluate the organism. If the return includes an intermediate stop at the ISS, then behavioral and imaging studies will be performed, and half the sample will be fixed for subsequent molecular and cellular studies. Complete molecular, behavioral, physiological, and morphological studies on return to Earth. In our opinion it is fundamental to conducting future manned deep space exploration that we first demonstrate to ourselves that terrestrial vertebrate life can not only survive a long duration space flight mission, but also that the vertebrate can adapt to the new environment and successfully readapt upon return to Earth. Information gleaned from other life forms is pertinent, but insufficient to elucidate the risks and consequences of higher life forms in space exploration.

This project will provide a diverse, living marine environment to sustain the vertebrate, and is in itself a rich ecological system. It is thought that early life on Earth was created and evolved from the sea. We will focus part of our analysis of the animal on sensory and neural systems. Of all the sensory structures within the vertebrate body the vestibular labyrinth is the most highly conserved among the species, from the bony fish (teleost) to mammals. Fossils from the Devonian period, over 400 millions ago, have revealed that the labyrinth geometry has remained strikingly similar in their living counterparts. In addition the ocean provides the richest food sources, and self-contained marine environment will do the same for exploration. Providing such a rich, diverse source of nutrients is fundamental to the settlement of the solar system by humans.